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Systems Analysis Office
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St. Louis, MO 63166

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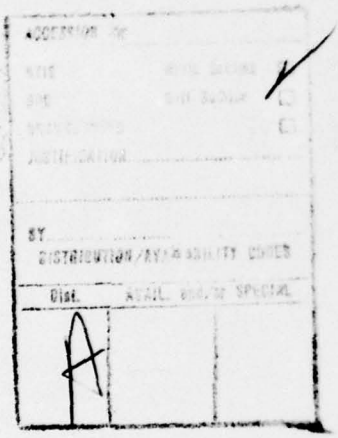

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This paper presents an overview of operations research and systems analysis, the typical role of a U. S. Army operations research/systems analysis organization, and an operations research/systems analysis applications matrix showing a number of the projects accomplished by the Systems Analysis Office, U. S. Army Aviation Systems Command. Additionally, a list of abbreviations and acronyms, and a glossary of terms germane to U.S. Army operations research/systems analysis are included.

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OPERATIONS RESEARCH/SYSTEMS ANALYSIS APPLICATIONS

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ABSTRACT

This paper presents an overview of operations research and systems analysis, the typical role of a U. S. Army operations research/systems analysis organization, and an operations research/systems analysis applications matrix showing a number of the projects accomplished by the Systems Analysis Office, U. S. Army Aviation Systems Command. Additionally, a list of abbreviations and acronyms, and a glossary of terms germane to U. S. Army operations research/systems analysis are included.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The roots of operations research can be traced back many decades, when early attempts were made to use a scientific approach in the management of organizations. However, the beginning of the activity called operations research has generally been attributed to World War II. Because of the war effort, there was an urgent need to allocate scarce resources to the various military operations and to the activities within each operation in an effective manner. Therefore, the British and subsequently the American military management called upon a large number of scientists to apply a scientific approach to dealing with this and other strategic and tactical problems. In effect, they were asked to perform research on military operations. These teams of scientists were the first operations research teams. Their efforts allegedly were instrumental in winning the Air Battle of Britain, the Island Campaign in the Pacific, the Battle of the North Atlantic, etc.

Spurred on by the apparent success of operations research in the military, industry gradually became interested in this field. As the industrial boom, following the war, was running its course, the problems caused by the increasing complexity and specialization in organizations were again coming to the forefront. It was becoming apparent to a growing number of people, including business consultants who had served on or with the operations research teams during the war, that these were basically the same problems but in a different context that had been faced by the military. In this way operations research began to creep

into industry, business, and civil government. By 1951, it had already taken hold in Britain and was in the process of doing so in these United States of America.

Operations research may be thought of as an activity that provides, through some form of measurement, advice to decision makers, or as its name implies, research on problems. It is frequently called by many other names, operational analysis, systems analysis, cost-benefit analysis, management science, etc. These names are given, often with different meanings, to the various cross sections of the activity that is concerned with problems of choice under risk or uncertainty, the allocation of scarce resources, for the present and future, the most effective ways of utilizing the already available resources, and the best choice from among a set of strategies, as circumstances and policies change.

2. OPERATIONS RESEARCH/SYSTEMS ANALYSIS

It is difficult to arrive at a single definition of operations research. The same statement can be made about systems analysis. Therefore, several definitions shall be offered for each of these terms.

Operations research is:

a. A research approach to problem solving for executive management.

b. A mathematical basis for the study and analysis of management problems for the purpose of making the soundest decisions possible.

c. The application of all branches of knowledge to the solution of problem.

Systems analysis is:

a. A reasoned approach to problems and decision making.

b. A quantitative common sense.

c. The application of methods of quantitative economic analysis and the research approach to the problems of choice.

d. An inquiry to aid a decision-maker in choosing a course of action by systematically investigating the proper objectives and comparing quantitatively (where possible) the costs, effectiveness, and risk associated with the alternative policies or strategies for achieving them, and formulating additional alternatives if those examined lack completeness.

Note that in the previous paragraphs there were several references made to the research approach (or scientific method). The following constitutes the research approach:

a. Formulate the problem

b. Construct the model(s)

c. Test the model(s)

d. Derive a solution from the model(s)

e. Test and control the solution

f. Implement the solution

(For additional information on the research approach, see Reference 1.)

Another approach that is important to operations researchers is the systems analysis approach. The following elements constitute the systems analysis appraoch:

a. Objective(s)

b. Alternative(s)

c. Cost

d. Model

e. Criterion

(For a definition of each of the terms used above, see Appendix C -- Glossary.)

3. ROLE: OPERATIONS RESEARCH/SYSTEMS ANALYSIS ORGANIZATION

In the context of the U. S. Army Materiel Development and Readiness Command (DARCOM), operations research/systems analysis is to be performed by distinct organizational elements which are composed of analysts who are trained in various scientific, engineering, and management science disciplines. (See Training below.) These organizations are not to be directly responsible for development, acquisition, or materiel readiness functions, but are to perform studies of the inherent alternatives that are or should be attendant with these functions. In accordance with the recent DARCOM realignment, it is anticipated that the primary operations research/systems analysis functions of the development and readiness commands will include, but not be limited to, a capability for performing analyses of requirements, decision risk analyses, independent evaluations, and trade-off analyses, and supporting the U. S. Army Training and Doctrine Command (TRADOC) and U. S. Army Test and Evaluation Command (TECOM). (See DARCOMR 11-1 for additional information.) Table 1 shows a partial listing of tasks that should be performed by an operations research/systems analysis organization throughout the life cycle of a system. (See also the operations research/systems analysis applications matrix, Appendix A.)

TABLE 1

LIFE CYCLE ANALYSIS AND MANAGEMENT OF SYSTEMS

I. CONCEPTUAL PHASE

- Best Technical Approaches
- Parametric Design Studies
- Cost-Effectiveness Analyses
- Cost-Benefit Analyses
- Trade-off Analyses

II. VALIDATION PHASE

- Technical Inputs to Joint Working Groups
- War Gaming
- Trade-off Analyses
- Evaluation of DT I and OT I Data
- Cost-Effectiveness Evaluations
- Special Task Force Studies
- Risk/Decision Risk Analyses

III. FULL-SCALE DEVELOPMENT PHASE

- Source Selection and Evaluation Board Participation
- Survivability Analyses
- Cost-Effectiveness Evaluations
- Trade-off Analyses
- War Gaming
- Evaluation of DT II and OT II Data
- Program Control and Schedules Management Analyses
- Trade-off Analyses
- Risk/Decision Risk Analyses

IV. PRODUCTION AND DEPLOYMENT

- Source Selection and Evaluation Board Participation
- Trade-off Analyses
- Systems Assessments
- Optimization Studies
- Foreign Military Sales Analyses
- Integrated Logistics Systems Evaluation
- Initial Provisioning
- Follow-on Provisioning
- Scheduling: Production and Maintenance
- Readiness

V. OPERATIONS AND MAINTENANCE

- War Gaming
- Operational Readiness
- Peacetime Replacement
- Depot Work Loading
- Queueing
- Management Information Systems
- Operational Effectiveness
- Comparative Analyses of Maintenance: Organic and Contractor
- Overhaul Facility Location Studies
- Transportation/Pipeline Analyses
- Part Management Analyses
- Determining the Conditions Under which a System/Subsystem Should be Overhauled
- Cost-Effectiveness Analyses

4. TRAINING

Three complimentary types of academic training are particularly relevant for a career in operations research. The first is basic training in the fundamentals upon which operations research is based. This includes the basic methodology of mathematics, science and business administration as well as such topics as linear algebra and matrix theory, probability theory, statistical inference, stochastic processes, computer science, microeconomics, accounting, organizational theory, and the behavioral sciences.

A second important type of training in operations research, include special techniques of the field such as mathematical programming, inventory theory, decision theory, scheduling theory, network flow theory, queueing models, reliability, game theory, and simulation. It should also include an introduction to the methodology of operations research, where the various techniques and their role in operations research study (involving specific problem areas) would be placed in perspective.

Finally, it is also well to have specialized training in some field other than operations research, for example, mathematics, statistics, industrial engineering, business administration, political science, economics, computer science, the social sciences, or the behavioral sciences.

Note one individual's breakdown of a selected set of academic courses which should be taken by operations researchers:

a. Decision Theory -- the formal specifications and analysis of choice situations in terms of the alternative actions available to the decision maker, the likely outcomes, and the preference ordering of all possible consequences.

b. Inventory Theory -- a prescriptive, process theory which mathematically models the behavior of inventory stocks as a function of the form of the inventory control policy and then seeks to optimize the basic "when to reorder and how much to reorder" decision variables.

c. Mathematical Programming -- a prescriptive body of theory of broad applicability to problems involving the allocation of limited resources to activities in such a manner that total activity output is maximized. It may be broken down into the following subset of courses: (1) Nonlinear Programming (Integer, Quadratic, and Convex Programming), and (2) Dynamic Programming

d. Network Theory -- the use of the physical concept of a network to represent routing problems, flow problems, or project management. Mathematical techniques then operate to find the shortest route, maximum possible flow, or minimum project completion time. PERT, CPM and other specialized applications of network theory have been developed for project managers.

e. Probability Theory -- the mathematical characterization of uncertainty. As most real world decisions involve elements of uncertainty (about future events or uncontrollables influences) such uncertainties need to be explicitly incorporated into decision analyses.

f. Queueing Theory -- a descriptive mathematical model of the design and planning of service facilities to meet randomly fluctuating demand for services such the the aggregate costs of idleness and waiting line (queue) congestion is minimal.

g. Reliability Theory -- a descriptive mathematical model of the probability that the system components and the total system will function satisfactorily during the performance of a mission.

h. Scheduling Theory -- a prescriptive theory dealing with the sequencing of events (i.e., orders processed through a job shop or time sharing in a computer system) so as to optimize some output measure like minimum time to accomplish all jobs or maximize the number of jobs completed on time.

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APPENDIXES

APPENDIX A

Operations Research/Systems Analysis

Applications Matrix

FIGURE 1. Operations Research/Systems Analysis Applications Matrix

Characteristics of O.R.	Application in Systems Analysis Work	Specific Examples
1. Challenge validity and sensitivity of major assumptions. Propose alternatives that might have otherwise been overlooked. Adversary vs Objective Bias.	1. Red Team reviews of PM's and AVSCOM functional managers.	1.a. ROMP (Review of Management Practices), CG directed study of management and decision-making related to engineering functions. b. RECAPS: AH-1, CH-47, AAH, HLH. c. Spare Parts and Component Breakout Studies. d. Low Dollar Value Item Study.
2. Collect and compare suspected related variables.	2. Regression Analysis and Inferential statistics.	2.a. Float Factors Study. b. OCM Profile Index Correlation Study. c. Termination Liability Curves. d. FY 75-80 Overhaul Predictions. e. PTRFs. f. MCR/RCM Study
3. Provide specific interdisciplinary assistance in quantifying results.	3. Trade-off Analyses and Optimization Studies.	3.a. CEFLY LANCER flying hour cost and performance parameters. b. COBRA PIP Implementation Study. c. ARADMAC Queueing Problem. d. CH-47 Modernization What-If Problem.

FIGURE 1. Operations Research/Systems Analysis Applications Matrix (Cont'd)

Characteristics of O.R.	Application in Systems Analysis Work	Specific Examples
4. Serve as consultants for management science studies.	4. Analysis of Functional Manager/Weapons Systems Manager Interface. Identification of issues and priorities affecting managers. Provision of ORSA indoctrination of foreign governments.	4.a. ROMP II b. Information briefing for Government of Iran.
5. Perform Risk/ Decision Risk Analyses: Networks/Probability/Computer Simulations.	5. Decision Risk Analyses to support complex decisions throughout the life cycle of material systems.	5. AAH and UTTAS DRA's.
6. War gaming analysis techniques.	6. Performance or direction of survivability studies and computer survivability simulations.	6. EVADE, GLOBAL, SOM.
7. Research-literature searching, computer algorithm development, methodology development.	7. Development of methodology for determining cost and effectiveness.	7.a. Life Cycle Analysis of Warranties on Aviation Equipment. b. Measures of effectiveness studies. c. TROSCOM PIP Life Cycle Model. d. Cost-Effectiveness Model I. Prototype Selection and Trade-Off Analyses. e. A Cost-Effectiveness Model, Choice Through Preferences. f. U. S. Army Aircraft Peacetime Replacement Factors.

FIGURE 1. Operations Research/Systems Analysis Applications Matrix (Cont'd)

Characteristics of O.R.	Application in Systems Analysis Work	Specific Examples
8. Collect expert opinions of forecasts over several iterations with feedback to panel members after each iteration.	8. Conduction of Delphi Technique to refine judgements of experts on critical problem areas.	8. UTTAS Delphi Study.
9. Conduct Cost-Effectiveness (C/E) Analysis.	9. Studies in support of Project Managers and R&D engineering.	9. Cost-Effectiveness Analysis of Air Mobile Shelters.
10. Quantitative Analyses:	10. Resource Studies in Support of Project Managers.	10.a. COBRA Implementation Study.
a. Mathematical Programming.		b. Allocation of Resources Model.
b. Network Analysis.		c. CH-47 Modernization Program Optimum Problem.
c. Statistics: Hypothesis Testing, Parametric Analysis, Confidence Limits, etc.		d. A Guide to Prototype Quantity Selection Study.

APPENDIX B

Abbreviations and Acronyms

ABBREVIATIONS AND ACRONYMS

AAH	Advanced Attack Helicopter
ADAPS	Automatic Display and Plotting Systems
ADDAR	Automatic Digital Data Acquisition and Recording
ADPE	Automatic Data Processing Equipment
ADX	Automatic Data Exchange
ALGOL	Algorithmic Language
ANACOM	Analog Computer
ANOVA	Analysis of Variance
AOC	Automatic Output Control
APL	A Programming Language; Assembly Programming Language
ASCII	American Standard Code for Information Interchange
ASE	Aircraft Survivability Equipment
ASH	Advanced Scout Helicopter
ASR	Automatic Send Receive
AUTODIN	Automatic Digital Network
AUTONET	Automatic Network
AUTOVON	Automatic Voice Network
BAL	Basic Assembly Language
BCD	Binary Coded Decimal
BIT	Binary Digit
BPI	Bits Per Inch
CAD	Computer-Aided Design
CDF	Cumulative Function
CEP	Circular Error Probability

CER	Cost Estimating Relationship
CETSA	Cost Estimating Techniques for Systems Acquisition
CLD	Computer Logic Demonstrator
COEA	Cost and Operational Effectiveness Analysis
CPC	Card Programmed Calculator
CPM	Critical Path Method
CPU	Central Processing Unit
CU	Control Unit
DAC	Direct Access Memory
DDC	Defense Documentation Center
DLSIE	Defense Logistics Studies Information Exchange
DIMES	Defense Integrated Management Engineering System
DMA	Defense Mapping Agency
DPI	Data Processing Installation
DRA	Decision Risk Analysis
DT	Development Test
DTUPC	Design-to-Unit Production Cost
DYNTACS	Dynamical Tactical Simulator
EAM	Electronic Accounting Machines
EBCDIC	Extended Binary Coded Decimal Information Code; Extended Binary Coded Decimal Interchange Code
EDP	Electronic Data Processing
EDPE	Electronic Data Processing Equipment
EDPM	Electronic Data Processing Machines

EOF	End of File
EOJ	End of Job
EOT	End of Tape
ESI	Externally Specified Index
EVADE	Evaluation of Air Defense Effectiveness
EWS	Electronic Warfare System
FDPC	Federal Data Processing Center
FEBA	Forward Edge of Battle Area
FHP	Flying Hour Program
FIFO	First In First Out
FOB	Forward Operating Base
FOSS	Family of Systems Studies
FSC	Federal Simulation Center
HLH	Heavy Lift Helicopter
HSDA	High-Speed Data Acquisition
HSP	High-Speed Printer
HSR	High-Speed Reader
IAS	Immediate Access Storage
IDP	Integrated Data Processing
IE	Independent Evaluation
IL	International Logistics
ILLIAC IV	Illinois Institute for Advanced Computing IV
ILS	Integrated Logistics Support
I/O	Input Output
IOC	Input/Output Comptroller; Input/Output Converter

IOCS	Input/Output Control Systems
IPR	In-Process Review
JWG	Joint Working Group
LCC	Life Cycle Cost
LIFO	Last In First Out
LOB	Logistics Operating Base
MN	Materiel Need
MPS	Mathematical Programming System; Multiprogramming System
OCM	On-Condition Maintenance
OT	Operational Test
PABX	Private Automatic Branch Exchange
PDF	Probability Density Function
PERT	Program Evaluation Review Technique
PIP	Product Improvement Proposal
PNVS	Pilot's Night Vision System
PTRF	Peacetime Replacement Factors
RAM	Random Access Memory; Reliability, Availability and Maintainability
RO	Read Only; Receive Only
ROC	Required Operational Capability
RPV	Remotely Piloted Vehicle
SCORES	Scenario Oriented Recurring Evaluation System
SEMA	Special Electronic Mission Aircraft
SOM	Sustained Operations Model

SSEB	Source Selection Evaluation Board
SSP	Scientific Subroutine Package
TADS	Target Acquisition and Designation System
TAERS	The Army Equipment Records System
TAMMS	The Army Maintenance Management System
TBO	Time Between Overhaul
UTTAS	Utility Tactical Transport Aircraft System
VERT	Venture Evaluation and Review Technique
XIC	Transmission Interface Converter

APPENDIX C

Glossary

GLOSSARY

Algorithm -- a procedure that always terminates.

Alternatives -- means by which it is hoped the objectives can be attained.

CEFLY LANCER -- a classified U. S. Army Security Agency Program.

Cost -- goods or services used or consumed.

Cost Effectiveness Analysis -- a study which entails the development of rank orderings of candidate systems or subsystems for meeting an approved requirement based on meaningful relationships between cost and operational effectiveness considerations.

Cost and Operational Effectiveness Analysis -- (See Cost Effectiveness Analysis.)

Criterion -- a rule or standard which may be employed to rank alternatives in the order of their desirability for choosing the most promising.

Decision Risk Analysis -- a rank ordering of the courses of action which result from a synthesis of the components of a system or subsystem which are derived from a detailed examination of the risk and an assessment of the mathematical expectation of value or utility of the schedule, cost, or technical components associated with a given concept, system, or phenomenon.

DELPHI -- a tool which is employed by analyst(s)(wherein expert panel members proceed through a series of questionnaire-feedback interations, while maintaining their anonymity, until a consensus is obtained) to obtain solutions to certain classes of problems.

Evaluation of Air Defense Effectiveness (EVADE) -- a computerized operational effectiveness (or survivability analysis) model.

GLOBAL -- (See EVADE.)

Independent Evaluation -- a comprehensive systems analysis of a concept or system which is to be performed before each major decision point. It entails a detailed analysis of the data (relevant to a system) and a rank ordering of the objective(s), requirement(s), and alternative courses of action of a system.

Inferential Statistics -- that branch of statistics which deals with the conditions under which one may infer important conclusions about a population based upon an analysis of a sample drawn from that population.

Maintenance Float Factors -- the percentage of a fleet of aircraft which are set aside (or designated) as substitute (or replacement) aircraft when the regularly assigned aircraft are down for maintenance beyond a specified period of time.

Mathematical Models -- models in which symbols represent quantities.

Maximum Combat Readiness/Reduced Casualties and Mishaps -- a study with the objective of reducing mishaps and increasing readiness by systematically programming the training for pilots and the flying hour program for the aircraft systems.

Method -- the way techniques are selected; a rule of choice; a procedure for evaluating alternative courses of action.

Methodology -- the study of scientific methods; the logis of science.

Model -- (noun) a representation of a physical or conceptual state, object or event; (verb) to demonstrate or show what a physical or conceptual state, object, or event is like.

On-Condition Maintenance -- a maintenance concept wherein the observed operating condition of the system dictates when the system is to be scheduled for maintenance in an overhaul/repair facility.

Operations Research -- research on operations; a branch of knowledge concerned with optimal decision making in, and modeling of, deterministic and probabilistic systems that originate from real life; the application of analytic methods which are adopted from mathematics, statistics, economics and other scientific and business disciplines for solving operational problems.

Optimal Solution -- the best solution choice from among the set of possible solutions.

Product Improvement Proposal (PIP) -- a document which precedes an engineering change proposal (ECP); a funding and planning document that describes the need, cost, description, and schedule for improving a given end item system.

Procedure -- a finite sequence of steps (or instructions) that can be carried out manually or mechanically.

Peacetime Replacement Factors (PTRFs) -- a set of parametric equations for enabling one to make quantitative predictions of aircraft losses on a yearly basis.

Risk -- the measure (or known probability) of failure that in associated with a given outcome that can be drawn from among the set of possible outcomes which result from a specific course of action.

Risk Analysis -- a systhesis of the components of a system or subsystem which are derived from a detailed examination of the risk and an assessment of the mathematical expectation of value or utility of the schedule, cost or technical components associated with a given concept, system, or phenomenon.

Satisficing -- a procedure for determining satisfactory solutions to real problems; application of qualitative and/or subjective methods to the attainment of an objective to ensure that it results in a state at least equal to its present state.

Simulation -- an abstraction or simplification of a real world phenomenon; a model which may be used to determine solutions to problems under varying conditions or circumstances.

Sustained Operations Model (SOM) -- a computerized logistical analysis model which may be employed in the evaluation of sustained combat operations.

System -- a set of objects (components) united by some form of interaction or interdependence.

Systems Analysis -- the formal examination of alternative system designs, strategies, concepts, and phenomena.

Technique -- a way of accomplishing a scientific objective; a scientific course of action.

Time Between Overhaul -- the number of operating hours established for a system or subsystem between scheduled overhauls.

Tool -- a physical or conceptual instrument that is used in scientific inquiry.

Trade-off Analysis -- a detailed evaluation of a system wherein alternative systems, subsystems, or components are analyzed in relations to the cost and operational effectiveness impact the substitute ones would have on the end item system or subsystem.

Uncertainty -- the unknown, unmeasurable, or meaningless probabilities of failure that are associated with a given set of outcomes that are consequences of a single or multiple course(s) of action.